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THEATER-CAPABLE UNMANNED AIRCRAFT SYSTEMS IN 2035—JOINT WARFIGHTING SYNERGY OR A JOINT LIABILITY?

by

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Biography

Lt Col John J. Menozzi graduated in 1992 from the United States Air Force Academy with a Bachelor of Science in Electrical Engineering. He earned a Masters in Organizational Management from George Washington University in 1999, and a Masters of Operational Art and Military Science from Air Command and Staff College, Maxwell AFB, AL, in 2006.

Lt Col Menozzi flew F-16's at Kunsan AB, S. Korea, Hill AFB, Utah, and Mountain Home AFB, Idaho. His staff assignments include 3rd Air Force and the Air Staff, where he worked as a Program Element Monitor for the Secretary of the Air Force, Acquisition.

Following Air Command and Staff College, he was assigned to Columbus AFB, MS, where he served as a T-6 Director of Operations, a T-38 Squadron Commander, and the 14th Operations Group Deputy. Lt Col Menozzi is a Command Pilot with more than 2,280 hours in fighter and trainer aircraft.

Introduction

> *The Department of Defense's vision for unmanned systems is the seamless integration of diverse unmanned capabilities that provide flexible options for Joint Warfighters while exploiting the inherent advantages of unmanned technologies, including persistence, size, speed, maneuverability, and reduced risk to human life. DoD envisions unmanned systems seamlessly operating with manned systems while gradually reducing the degree of human control and decision making required for the unmanned portion of the force structure.*
>
> *--2011 DoD Unmanned Systems Roadmap*[1]

> *July 31, 2035: An Air Force MQ-La, with SAR/GMT advanced SIGINT capabilities, while conducting wide-angle persistent surveillance of a Middle Eastern country, detects movement of a convoy of vehicles potentially transporting stolen nuclear material for manufacturing weapons of mass destruction (WMD). Via multi-spectral secure data links, the MQ-La cues an MQ-X in the area to initiate FMV surveillance and assume on-scene command duties. The MQ-X locates the convoy, then cross-cues a US Army Sky Warrior armed with the latest in CBRNE detection equipment to verify the presence and type of nuclear material, and initiates coordination with US Army Special Forces ground personnel stationed near the country border for potential convoy interdiction. Thanks to the seamless integration of a resilient wideband secure network, the MQ-X feed is rapidly linked to the Joint Force Commander (JFC), who is apprised of the situation and makes the decision to attempt a covert interdiction later that night using the Special Forces team supported by multiple armed MQ-X platforms. Utilizing the US Army's recently fielded Common Control Interface, the Special Forces team is provided real-time FMV and threat updates and is able to successfully interdict and recover the stolen nuclear material, averting a potential WMD attack.*

The strategic environment and national security challenges confronting the United States in the next 25 years are complex and uncertain, characterized by an ever-accelerating pace of change. The rise of new global powers, increased influence of non-state actors, proliferation of WMD technologies, and the evolution of several profound socio-economic challenges will threaten international order and security. Unmanned aircraft systems (UAS), leveraging strengths of persistence, versatility and reduced risk to human life, provide a vital synergistic capability toward countering these 2035 threats. However, in order to realize the untapped

[1] Department of Defense. *Draft Unmanned System Integrated Roadmap, FY 2011-2036.* (Washington D.C.: Office of Secretary of Defense, Unpublished Draft), 3.

potential of UAS, the services must make a significant course correction—agreeing now to focus on increased system interoperability and overcoming several sources of friction in the stove-piped ways these systems are currently developed, procured, and employed.

Problem Statement

The past decade has seen UAS play a growing role in US military operations, with JFCs embracing the unique capabilities provided by unmanned technologies across an ever-expanding mission set. Operations in Afghanistan and Iraq have validated UAS capability to drastically increase situational awareness and provide critical effects throughout the battlespace. In response to warfighter demand, UAS acquisition to date has consisted of individual services short-circuiting normal DoD acquisition processes and fielding service-specific, proprietary, stand-alone systems as rapidly as possible. Since 2001, this process has been fueled largely by Congressional wartime supplemental budget authorizations. While this approach is laudable for averting the bureaucratic acquisitions process and getting capability quickly to the warfighter, first-generation UAS possess minimal interoperability and are extremely costly to modernize. Continuing down this path limits joint interoperability and available investment for system and UAS C3 infrastructure modernization required to counter future threats.

Three primary sources of friction influence today's theater-capable UAS environment—friction within DoD and the services, friction between Congress and DoD, and friction between DoD and the defense industry. Lacking centralized DoD oversight, the services have rushed to field proprietary systems to support today's fight without defining key interface standards or collaborating to achieve commonality among subsystems, payloads, or ground control stations.[2]

[2] US Government Accountability Office, *Defense Acquisitions: DoD Could Achieve Greater Commonality and Efficiencies among Its Unmanned Aircraft Systems,* Testimony before the Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, House of Representatives (Washington D.C.: US Government Accountability Office, March 23, 2010), preface.

Further, as UAS capabilities and missions have expanded, inter-service rivalries have sparked over UAS C2, service roles and missions, and control over large portions of budget authority and prestige.

Competition between the services to fund expensive, stove-piped UAS acquisition programs has also resulted in increased congressional criticism and oversight. Congress has sought to balance support for funding critical warfighter requirements with the obligation to efficiently spend taxpayer defense dollars. Several Government Accountability Office (GAO) reports highlight congressional frustration with limited UAS mission effectiveness and affordability.[3] This criticism, coupled with a shrinking defense budget has forced DoD to consider a more effective, affordable modernization plan.

A third source of friction exists between DoD and the defense industries that develop and manufacture UAS. The sole-sourced, proprietary UAS acquisition model of today limits competition, stifles innovation, and holds DoD hostage to exorbitant modernization costs. To meet the challenges of the 2035 threat environment, DoD must work with defense industry to reform UAS acquisition.

This paper argues that the challenges of joint interoperability and future C3 of theater-capable UAS must be addressed today. Failure to do so places the warfighter of 2035, who will depend on joint UAS support, at significant risk. First, it benchmarks the state of first-generation theater-capable UAS integration in the joint battlespace, highlighting existing C3 shortfalls and identifying root causes plaguing current UAS acquisition. After a review of the 2035 threat environment and expected UAS C3 vulnerabilities, it defines likely future theater-capable UAS mission types and the resultant macro-level C3 requirements and key enabling technologies that must be pursued. Next, the paper provides an analysis, comparing future C3 requirements

[3] Ibid.

against postulated functional solutions identified in service and DoD UAS Roapmaps. Specifically, this analysis identifies critical C3 enabling technologies that must be interoperable and standardized to optimize UAS effectiveness and efficiency. Finally, the paper provides recommendations to improve theater-capable UAS interoperability and focus joint development and implementation efforts toward realizing DoD's long-term UAS vision.

Research Methodology, Scope, and Assumptions[4]

To narrow the scope of discussion, this paper focuses on interoperability and C3 issues specific to theater-capable UAS. According to the Joint Concept of Operations for Unmanned Aircraft Systems published by JFCOM:

> *Theater-capable UAS are considered those UAS that have the capability to support joint operations across the entire Area of Responsibility (AOR) because of their size, range, endurance, and BLOS communication capability. They generally are those UAS that fall under Group 4 or 5. The theater-capable nature of these UAS requires additional considerations to balance the CFC requirements with the functional component commander requirements.*[5]

Figure 1. provides a breakdown of current and future DoD UAS platforms, with theater-capable UAS highlighted in Groups 4 and 5.

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[4] The researcher conducted archival research on DoD and service UAS Roadmaps as well as a literature review of available articles, papers, and briefings on current and future UAS C3 capabilities and requirements. Additionally, subject matter expert (SME) interviews were conducted with several government, industry, and academic experts in the UAS field. Specifically, the author interviewed UAS operations experts, service requirements and strategic planners, and research and development leaders, both at Air Force Research Lab (AFRL) and the Defense Advanced Research Products Agency (DARPA). Additionally, several SMEs from the Office of the Secretary of Defense, Acquisition and Technology (OSD/AT&L) were interviewed to gain perspective on the current level of OSD and Joint Staff oversight and involvement in implementing joint solutions to future UAS C3. This paper is based on unclassified information and assumes a working-level familiarity with basic UAS terminology and definitions, as well as a basic understanding of current theater-capable UAS employment CONOPs.

[5] United States Joint Forces Command. *Joint Concept of Operations for Unmanned Aircraft Systems*, (Creech AFB, NV, Joint Forces Command, April 2010), III-2.

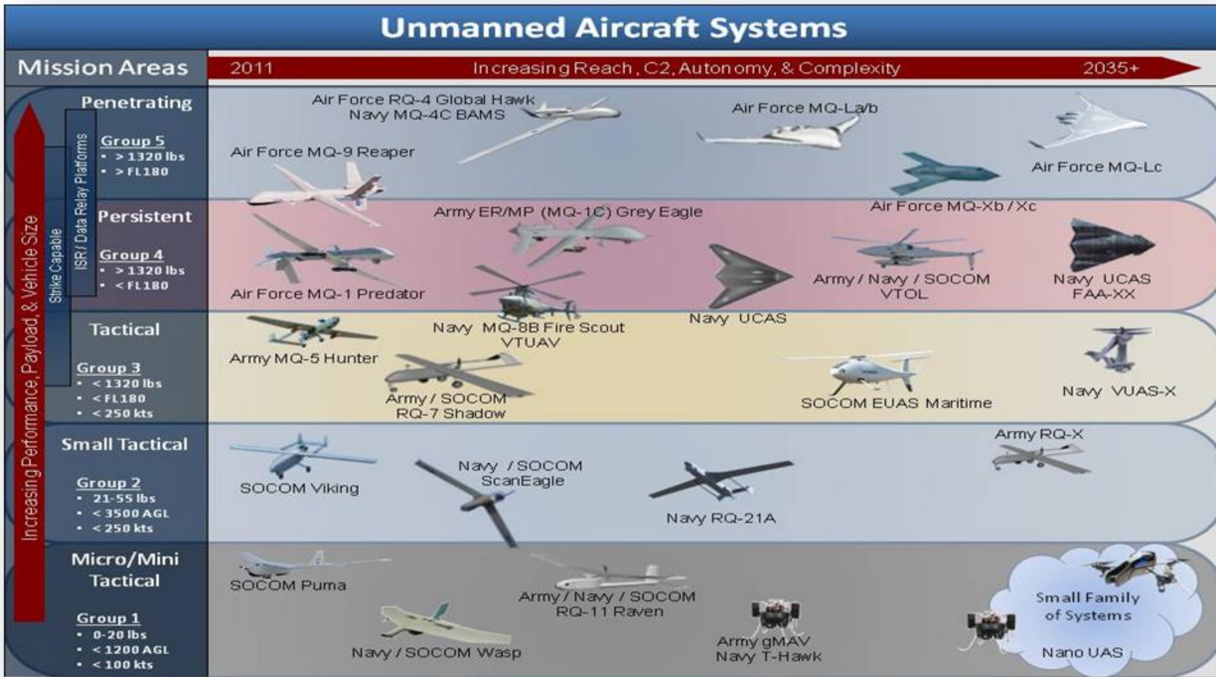

Figure 1. DOD UAS Family of Systems[6]

Current Situation

Over the past decade, UAS have played an ever-increasing role in US military operations. The air domain has received the greatest focus as DoD and the JFCs have embraced the unique capabilities provided by unmanned technologies. Originally, the UAS mission focused primarily on tactical reconnaissance; however, this has expanded to include most capabilities within the ISR mission area, battlespace awareness, and strike missions including both time critical targeting and CAS.[7] Table 1 reflects the 2011 President's Budget request allocated to UAS, and highlights the continuing expansion to satisfy warfighter demands.

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[6] Reprinted from: Department of Defense, *Draft Unmanned System Integrated Roadmap—FY2011-2036*, 12.
[7] Ibid., 11.

Table 1. 2011 President's Budget for Unmanned Systems[8]

System	Funding Source	FY09	FY10	FY11	FY12	FY13	FY14	FY15	Total
UAS	RDT&E	1,038.9	1,234.1	1,275.2	1,147.6	1,211.8	720.4	657.9	7,285.8
	Proc	2,130.3	3,266.6	4,150.2	3,390.4	3,403.1	3,800.6	3,847.9	23,989.0
Tot O&M (3,900 in'08)		4,530	5,400						

FY = fiscal year; RDT&E = research, development, test, and evaluation; Proc = procurement; O&M= operations and maintenance

Currently, over 10 different UAS and over 6,500 individual aircraft are fielded and/or deployed across the four Military Services and Special Operations Command (SOCOM). These systems are detailed in Table 2.

[8] Reprinted from: Department of Defense, *Draft Unmanned System Integrated Roadmap—FY2011-2036* ,10.

Table 2. DoD UAS Inventory[9]

UAS Systems in the Field		Service	Systems	Aircraft
RQ-4	Global Hawk (Block 10)	USAF/Navy	3	9
MQ-9	Reaper	USAF/Navy	1	54
MQ-1	Predator / Grey Eagle	USAF/Army	10	191
MQ-5	Hunter	Army	6	25
RQ-7	Shadow	Army/USMC	91	364
N/A	ScanEagle	USAF/Navy	13	122
RQ-11	Raven	USAF/Army/USMC/SOCOM	1782	5346
RQ-16	gMAV	Army/Navy	194	377
N/A	WASP	USAF/USMC	243	756
N/A	sUAS AECV	SOCOM	13	39
UAS Systems in Development or Demonstration		**Service**	**Systems**	**Aircraft**
RQ-4	Global Hawk (Block 20, 30, 40)	USAF	1	15
MQ-4	BAMS	Navy	0	0
MQ-8	FireScout	Navy	0	17
R22	Maverick	SOCOM	1	3
A160T	Hummingbird	SOCOM/DARPA/Army	0	8
RQ-21A	STUAS/TIER II	Navy/USMC	0	0
N/A	UCAS Demo	Navy	0	2

* Inventory as of 01 September

AECV = All Environment Capable Variant CV = Carrier Vehicle DARPA = Defense Advanced Research Projects Agency	gMAV = gasoline-powered Micro Air Vehicle STUAS: Small Tactical UAS sUAS = small UAS UCAS = Unmanned Combat Aircraft System

As the number of fielded systems has expanded, flight hours have dramatically increased. In 2009, DOD operated almost 500,000 UAS flight hours in support of Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF).[10] These systems continue to demonstrate their value in combat operations across a broader mission set, and will continue to proliferate across the joint battlefield.

[9] Reprinted from: Department of Defense, *Draft Unmanned System Integrated Roadmap—FY2011-2036*, 12-13.
[10] Ibid., 13.

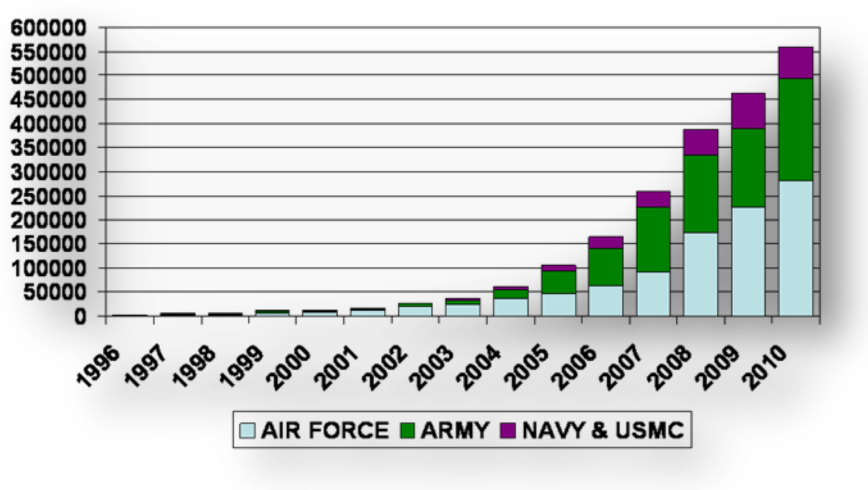

Figure 2. UAS Flight Hours (1996-Present) Updated 30 Sep 2010[11]

Despite a high level of UAS mission success in ongoing operations, the dramatic increase in demand for, and use of, these assets has caused friction within DoD, including service-specific UAS acquisition programs and the integration of UAS into combat operations.[12] The desire to rapidly deliver capability to the warfighter has led to UAS procurement outside normal acquisition channels via service-specific, proprietary acquisition programs, resulting in the majority of theater-capable UAS, once fielded, exhibiting a lack of interoperability and synergy.[13] Examples include the failure of some systems to meet joint service requirements and communication standards, leading to data exchange issues even within the same service, as well as a failure to deconflict datalink frequencies across systems, resulting in bandwidth saturation

[11] Reprinted from: Department of Defense, *Draft Unmanned System Integrated Roadmap—FY2011-2036*, 13.

[12] US Government Accountability Office, *Unmanned Aircraft Systems: Additional Actions Needed to Improve Management and Integration of DoD Efforts to Support Warfighter Needs,* Report to the Subcommittee on Air and Land Forces, Committee on Armed Services, House of Representatives (Washington D.C.: US Government Accountability Office, November, 2008), 1. Synopsis of GAO Assessment.

[13] United States Air Force, *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047.* (Washington D.C., Headquarters, United States Air Force, 18 May 2009), 63. In this document the Air Force states that all current UAS were acquired outside the normal JCIDS process, through the supplemental funding of an Advanced Concepts Technology Demonstration (ACTD). The Army's Sky Warrior was also acquired outside the normal JCIDS process, through an Urgent Mission Needs and the Rapid Acquisition Process. [James Hasik, "Al Qaeda doesn't have a JCIDS process—thoughts on institutionalizing rapid acquisition." http://www.jameshasik.com/weblog/2010/10/al-qaeda-doesnt-have-a-jcids-processthougths-on-institutionalizing-rapid-acquisition.html (accessed 17 January 2011).]

and unintentional interference.[14] GAO testimony in 2006 cited that, according to DoD "many elements are needed for the use of UAS, including a systems architecture that allows data to be moved, adequate spectrum and bandwidth for communication, airspace management and deconfliction, common data standards and formats to allow sharing and data fusion, common operating systems, and system interoperability."[15] Despite DoD's awareness of these issues, 2010 GAO testimony indicates little progress has been made, stating "Although several programs achieved airframe commonality, service-driven acquisition processes and ineffective collaboration were key factors that inhibited commonality among subsystem, payloads, and ground control stations, raising concerns about potential inefficiencies and duplication."[16]

Senior DoD leadership appears intent on balancing the friction of external management criticisms from GAO and Congress with internal service factions' intent on maintaining the ability to organize, train, and equip their forces. DoD non-concurred with a GAO recommendation to "designate a single departmental entity that is responsible and accountable for integrating all cross-cutting DoD efforts related to improving the management and operational use of UAS."[17] Instead, the department created the UAS Task Force in lieu of an executive agent, and also established capability portfolio managers to coordinate the expanding UAS roles across multiple portfolios.[18] DoD also non-concurred with a GAO recommendation to "develop a comprehensive and integrated UAS strategic plan, in coordination with the

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[14] US Government Accountability Office, *Unmanned Aircraft Systems: Additional Actions Needed to Improve Management and Integration of DoD Efforts to Support Warfighter Needs*, 1.

[15] US Government Accountability Office, *Unmanned Aircraft Systems: Improved Planning and Acquisition Strategies Can Help Address Operational Challenges,* Testimony before the Subcommittee on Tactical Air and Land Forces, Committee on Armed Services, House of Representatives (Washington, D.C.: US Government Accountability Office, April 6, 2006), 5.

[16] US Government Accountability Office, *Defense Acquisitions: DoD Could Achieve Greater Commonality and Efficiencies among Its Unmanned Aircraft Systems,* Testimony before the Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, House of Representatives (Washington D.C.: US Government Accountability Office, March 23, 2010), preface.

[17] US Government Accountability Office, *Unmanned Aircraft Systems: Additional Actions Needed to Improve Management and Integration of DoD Efforts to Support Warfighter Needs,* 27-28.

[18] Ibid, 28-29.

services, to align UAS goals and funding with long-term departmental planning efforts."[19] DoD insisted that the long-term goals and guidance for achieving them are provided in top-level documents such as Guidance for the Development of the Force, and enforced through the structured Joint Capabilities Integration Development System (JCIDS) process.[20] Further, DoD restated its "reliance on the UAS Task Force to translate the department's capabilities-based strategic plan into the platform and technology-based 'Unmanned Systems Roadmap' to share with external stakeholders and industry."[21] While the UAS Task Force acts as advisors and has implemented OSD's recommendations for increased oversight and identification of commonality, it is important to note that they do not have direct decision-making or resource allocation authority.[22] Significant work remains to reform the UAS acquisition system and enable interoperability and commonality required to achieve DoD's long-term UAS vision.

In addition to acquisition realities limiting interoperability and joint employment synergy, several doctrine, organizational, process, and infrastructure challenges affect current and future UAS C3. As the roles, missions, capabilities and number of fielded theater-capable UAS continues to expand, two key C3 issues have been highlighted. The first evolved from the Air Force's Remote Split Operations (RSO) UAS employment CONOPs for theater-capable assets, whereby centralized reachback operations and beyond-line-of-sight (BLOS) communication are used to control deployed UAS platforms in theater (see Figure 3 below).

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[19] Ibid., 28.
[20] Ibid., 30.
[21] Ibid.
[22] US Government Accountability Office, *Defense Acquisitions: DoD Could Achieve Greater Commonality and Efficiencies among Its Unmanned Aircraft Systems,* 10.

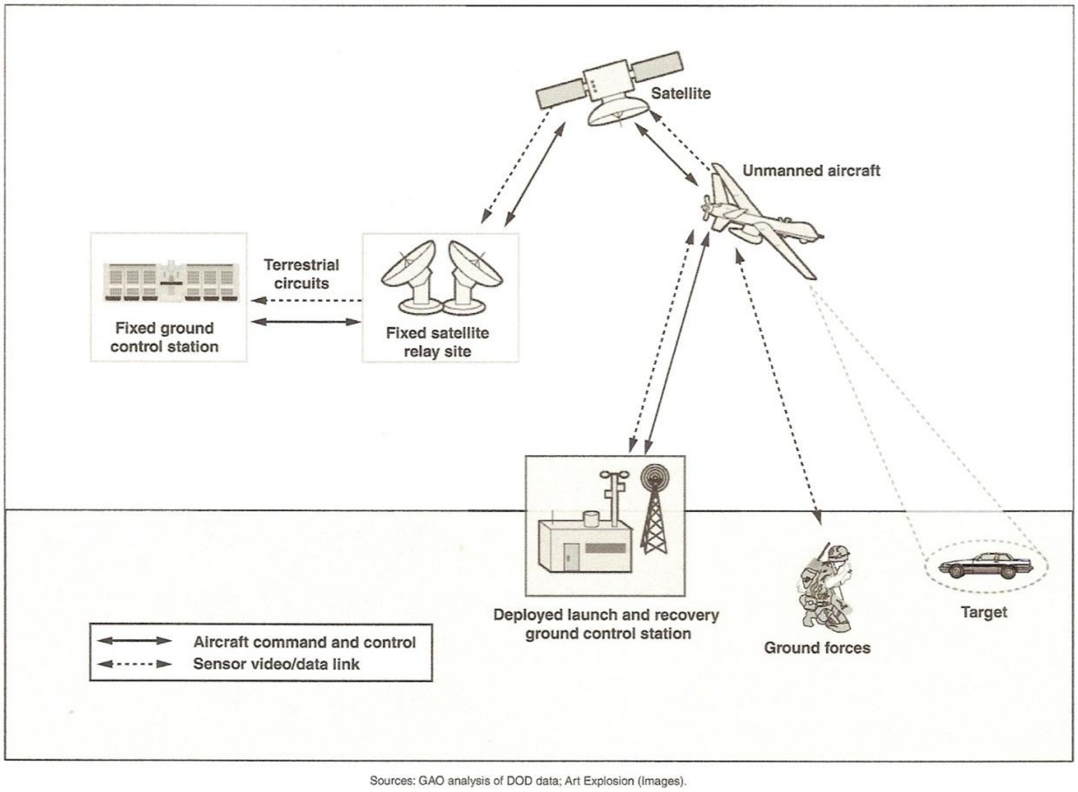

Figure 3. Beyond Line of Sight (BLOS) UAS Operational Concept[23]

Although Air Force theater-capable UAS operations to date have almost exclusively supported the CENTCOM AOR, the proliferation of UAS and expanding COCOM demands have raised the question of how to effectively provide C2 to UAS operators utilizing RSO to support multiple COCOMs simultaneously. According to Title 10, United States Code, section 164, "non-transferable command authority is exercised only by commanders of unified or specified combatant commands unless otherwise directed by the President or SECDEF."[24] Unlike the allocation of strategic airlift through the Tanker Airlift Control Center (TACC), multi-role, long range UAS do not currently have an overarching functional COCOM that can

[23] Reprinted from US Government Accountability Office, *Unmanned Aircraft Systems: Comprehensive Planning and a Results-Oriented Training Strategy Are Needed to Support Growing Inventories,* Report to the Subcommittee on Air and Land Forces, Committee on Armed Services, House of Representatives (Washington D.C.: US Government Accountability Office,March, 2010), 19.

[24] United States Air Force, *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047.* (Washington D.C., Headquarters, United States Air Force, 18 May 2009), 53.

reallocate resources between theaters.[25] As stated in the USAF UAS Flight Plan, "this is further exacerbated within a theater because today two separate organizations can task UAS assets—the Joint Functional Component Commander (JFCC) for Intelligence, Surveillance, and Reconnaissance (ISR) as well as the Joint Force Air Component Commander (JFACC) through the Air Tasking Order (ATO)."[26] In addition to the broader Joint Doctrine question of inter-theater UAS allocation, the current system of dual tasking UAS assets within an AOR through both ATO and ISR collection channels can create unnecessary, wasteful duplication in a resource-constrained environment.[27] Solutions to these C2 challenges will require doctrinal, organizational, and process changes to establish a global allocation and tasking process for theater-capable UAS and minimize unnecessary dual-tasking.

The proliferation of first-generation theater-capable UAS has also highlighted limitations and weaknesses in the existing DoD communication infrastructure. The interoperability, lack of common data standards, and bandwidth deconfliction issues raised earlier in this chapter indicate that significant work remains to achieve the long-range UAS vision for a flexibly autonomous, resilient, open-architecture, networked system of systems[28]. The Air Force's reliance on commercial-off-the-shelf (COTS) data link equipment and an RSO C2 CONOPS that is dependent on competitively-leased commercial SATCOM bandwidth is a major long-term risk to system viability and security.[29] According to the USAF UAS Flight Plan, "despite projected Military Satellite Communication (MILSATCOM) growth over the next 20 years, the lack of synchronization between the on-orbit segment and the fielding of UAS's without compatible terminals will drive the Air Force to continue to rely on commercial or 'surrogate satellite'

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[25] Ibid.
[26] Ibid.
[27] Maj. Julian C. Cheater, USAF. "The War Over Warrior: Unmanned Aerial Vehicles and Adaptive Joint Command and Control." (Maxwell AFB, AL: Air University Press, June 2008), 17.
[28] United States Air Force, *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047* , 15.
[29] Ibid., 43.

alternatives."[30] In addition to recurring costs of approximately $25M annually, satellite systems are vulnerable to several threats, including jamming, interference, interception, physical or electronic attack, and intrusion.[31] Significant joint coordination and investment must be undertaken to migrate from today's dependency on commercial SATCOM control to a tiered network system capable of providing assured communications for joint theater-capable UAS operations.

Inventories of theater-capable UAS continue to expand, meeting a growing number of warfighter requirements. However, current service UAS acquisition programs suffer from a lack of DoD enterprise-level oversight, which has resulted in a failure to define baseline interoperability standards to govern an open system design architecture. Several evolving theater-capable UAS C3 issues also exist, including weaknesses in the DoD communication infrastructure and joint command, control, allocation and tasking challenges that must be resolved. To systematically address these issues, it is necessary to look beyond today's benign operating environment and consider the dynamic nature of the future threat.

2035 Threat Environment

> *The next quarter century will challenge US joint forces with threats and opportunities ranging from regular and irregular wars in remote lands, to relief and reconstruction in crisis zones, to cooperative engagement in the global commons. Our enemy's capabilities will range from explosive vests worn by suicide bombers to long-range precision-guided cyber, space, and missile attacks. The threat of mass destruction—from nuclear, biological, and chemical weapons—will likely expand from stable nation-states to less stable states and even non-state networks.*
>
> *--The Joint Operating Environment (JOE) 2010*[32]

[30] Ibid.
[31] Ibid., 44-45.
[32] United States Joint Forces Command, *The Joint Operating Environment 2010.* (Norfolk, VA, United States Joint Forces Command, 2010), introduction.

The security environment of 2035 will be influenced by several trends, including advances in the fields of cyber, space capabilities and utilization, and the exponential growth and proliferation of technology. Advances in communication and information technologies, including global networks enabled by wireless and broadband connectivity, will significantly improve the capabilities of the joint force.[33] Many of these same advances will be used by America's enemies to asymmetrically attack, degrade, and disrupt blue-force ISR and C3 networks. To counter this threat, the joint force must possess resilient, multi-spectral communication links capable of functioning in a hostile information environment.

By 2035, US preeminence in space will be offset by the proliferation of more affordable launch and satellite capabilities and the further development of anti-satellite weapons.[34] According to the JOE 2010, "The relative vulnerability of space assets plus our heavy reliance on them could provide an attractive target for a potential adversary."[35] In addition to the advancement of cyber and space threats, an adversary could develop and use one of several disruptive technologies to asymmetrically attack US forces. Examples include an electro-magnetic pulse weapon against un-hardened equipment, as well as the use of advanced laser or high-powered microwave systems.[36]

Unlike America's ongoing wars in Afghanistan and Iraq, planners for future conflicts must factor in two important constraints: logistics and access.[37] Given the proliferation of cyber warfare and longer-range, precise weapons, potential enemies will be capable of threatening the projection of US forces into a theater, as well as their logistical supply chains.[38] Projection of military power in the future will likely require enabling efforts, and must account for the

[33] Ibid., 34.
[34] Ibid., 36.
[35] Ibid., 37.
[36] Ibid., 55.
[37] Ibid., 63.
[38] National Intelligence Council, *Global Trends 2025: A Transformed World,* November 2008, xi.

domains of cyber and space as part of the "global commons."[39] Critical enablers, including robust, networked ISR and intelligence preparation of the battlespace (IPB), must have redundancy built in to preclude disruption through a single point of attack by an enemy. Summarizing this point in the JOE 2010, "the battle for access may prove not only the most important, but the most difficult."[40]

UAS C3 Requirements in 2035

In order to forecast UAS C3 requirements for 2035, it is important to consider the range of current and future missions of theater-capable UAS. According to the Joint CONOPS for UAS, theater-capable UAS are currently used for three types of mission: ISR/Reconnaissance Support and Target Acquisition (RSTA), support to C2, and Joint Fires.[41] ISR/RSTA, in this context, "describes the process of building activity patterns through a large number of repeated visits at a large set of targets and requires exploitation to develop actionable intelligence."[42] Support to C2 "involves the collection of real-time, actionable, and often perishable data in direct support of the mission of a ground commander, and may involve hours of staring at a single target or examining planned routes."[43] Support to Joint Fires "involves the development of targeting data, the use of laser designation, or actual employment of a weapon, and may occur in the course of another type of mission or may be preplanned."[44]

In a permissive or contested environment of 2035, it will still be necessary to employ networked theater-capable UAS in ISR/RSTA and support to C2 missions to find, fix, target, track, and potentially engage high value targets. This scenario will stress the C3 architecture in

[39] United States Joint Forces Command, *The Joint Operating Environment 2010*, 63.
[40] Ibid.
[41] United States Joint Forces Command. *Joint Concept of Operations for Unmanned Aircraft Systems*, (Creech AFB, NV, Joint Forces Command, April 2010), III-3.
[42] Ibid.
[43] Ibid.
[44] Ibid.

terms of bandwidth available for full-motion video (FMV) and data transmission, processing, exploitation, and dissemination (PED). Operations in a contested environment, where a resourceful adversary may attempt to disrupt, degrade or destroy not just the UAS platform but also the C3 architecture will require a secure, resilient, multi-spectral network capable of withstanding cyber or counter-space attacks. Conversely, employing theater-capable UAS in a denied access environment, leveraging platform self-protection measures such as stealth, speed, and electronic attack (EA), will require a C3 architecture capable of advanced levels of automation and limited, secure, low-probability of intercept (LPI) communications.

The C2 of current and future theater-capable UAS missions, regardless of threat spectrum, will benefit from the development and dissemination of a networked common operating picture (COP). The long-term objective of an open-architecture, secure, resilient network not only enhances information sharing and situational awareness, but enables self-synchronization, dramatically increasing mission effectiveness.[45] A robust network, along with advances in artificial intelligence and automation, will enable long-term theater-capable UAS mission growth into such areas as denied-access Suppression of Enemy Air Defenses (SEAD) and strike roles. Additionally, when utilized as an aerial communications relay node in parallel with other missions, UASs provide network resiliency and redundancy as well as the capability to extend the network to more units operating across the battlespace.[46]

Interoperability and C3 Analysis

DoD, the services, Congress and the GAO have all struggled to define appropriate levels and focus of "jointness" for theater-capable UAS. As the capabilities and joint mission areas

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[45] US Department of Defense, Office of Force Transformation, *The Implementation of Network-Centric Warfare* (Washington, D.C.: US Department of Defense, 5 January 2005), 7.

[46] LTC Duane T. Carney, USA. "Unmanned Aircraft Systems Role in Network Centric Warfare," 2008, http:///www.csl.army.mil/usacsl/publications/InfoAsPower3/IAP3%20-%20Section%20Two%20-%20Carney.pdf (accessed on 4 September 2010), 95.

served by UAS continue to expand and overlap, so has the requirement to improve their management and integration across DoD to better support joint warfighter needs. The requirement for a responsive acquisition system that delivers timely, effective capability must be balanced by a fiscally responsible approach that optimizes joint interoperability and minimizes wasteful duplication of effort.

The criticisms and weaknesses of current theater-level UAS are well documented and must be addressed. This paper does not seek to continue debating the merits of appointing a Service Executive Agent for UAS, as DoD leadership has instead chosen to establish a task force structure to provide centralized enterprise oversight. Nor does it argue the case for a single service to provide C2 for all theater-capable UAS. It recognizes the operational utility gained by simultaneously pursuing in-theater and RSO UAS C2 CONOPS as the services develop alternative capabilities for the warfighter.

It strives instead to implore warfighters, OSD leadership, service acquisition experts, and defense industry to partner and improve significant shortfalls such as bandwidth saturation, secure network connectivity, and UAS C2 doctrine questions. The solution does not mandate total platform commonality or single-service C2 of theater-capable UAS. Rather, it must define and implement key interface standards that enable interoperability, improve joint employment CONOPS and coordinate infrastructure investment to minimize C3 seams and maximize effectiveness against future threats.

Interoperability, defined as the ability to operate in synergy in the execution of assigned tasks,[47] does not necessarily require a single common airframe or contractor. Rather, if properly implemented through common information, data exchange, and component interface protocols, it

[47] Definition found in Joint Publication (JP) 1-02, Department of Defense Dictionary of Military and Associated Terms, 12 April 2001 (as amended through 17 March 2009).

can enable networked communication and optimize C2 flexibility, exponentially improving joint warfighting capabilities. According to DoD's 2011 Unmanned Systems Roadmap, unmanned systems will need to demonstrate interoperability in a number of realms, each being critical to achieve long-term C3 requirements for theater-capable UAS:[48]

- *Among similar components of the same or different systems.* The plug-and-play use of different sensors on an unmanned vehicle.
- *Among different systems of the same modality.* A common GCS for multiple, heterogeneous UAS.
- *Among systems of different modalities.* The ability of ground, air, and maritime vehicles to work cooperatively.
- *Among systems operated by different Military Departments under various CONOPS and TTPs.* Joint systems working together to execute a common mission.
- *Among systems operated and employed by coalition and allied militaries using various TTPs (such as NATO STANAGs).*
- *Among military systems and systems operated by other entities in a common environment.* The ability of military UAS to share the National Air Space with commercial traffic.
- *Among systems operated by non-DoD organizations, allies, and coalition partners.* The ability for organizations such as the Department of Homeland Security assets to exchange information with DoD assets of the same modality and model.

Specifically, joint theater-capable UAS must jointly develop an open architecture that contains:[49]

- *common capability descriptions in their requirements*
- *common, open data models, standards, interfaced and design architectures*
- *common components in their acquisition strategies*

If interoperability is to be improved, OSD, through the UAS and ISR Task Forces, must pursue development, documentation, and adherence to baseline design standards specific to the ISR enterprise. As stated by Kostka in his *Joint Forces Quarterly* article, "Adherence to a well-documented set of baseline standards during the design phase of ISR systems development allows these structures to interact and results in substantial cost savings, interoperability, and

[48] Department of Defense. *Draft Unmanned System Integrated Roadmap—FY2011-2036*, 22-23.
[49] Ibid., 24.

efficiency benefits over the life cycle of the program."[50] While the main goal of baseline standards is interoperability, a standards-based systems development approach can also be applied to operating systems, data bus interfaces and schemas, and messaging standards.[51] If these fundamental definitions for open system architecture can be standardized, it paves the way for the theater-capable UAS community to jointly address the issues of data portability between systems, airspace integration and networked communications.[52]

Advances in UAS onboard communication and underlying network infrastructure must also be jointly coordinated and compliant with baseline design standards to succeed. As highlighted in the 2011 DoD Unmanned Systems Roadmap:

> *To support DoD's goal of attaining better bandwidth efficiency, improving transmitter and receiver efficiencies, and requiring less size, weight, and power (SWaP), communication systems need to support multiple frequency bands, limited bandwidth, variable modulation schemes, error correction, data encryption, compression, and network discovery. All of this must be done while minimizing interference from or to other near-by spectrum dependent systems.*[53]

Achieving joint standardization of network waveforms and the development and fielding of advanced communications technologies to ensure a resilient, secure network will be the most significant hurdle toward achieving DoD's long-term UAS vision espoused at the outset of this paper.

Advances in communication technology that address the issues of SATCOM bandwidth saturation and aerial network resiliency are technologically challenging and expensive to develop. First generation UAS networking, utilizing CDL technologies, does not field until

[50] Kostka, Del C., "Moving Toward a Joint Acquisition Process to Support ISR," *Joint Forces Quarterly*, 4th Quarter 2009. http://www.ndu.edu/press/lib/images/jfq-55/11.pdf, 74.
[51] Ibid.
[52] Department of Defense, *Draft Unmanned System Integrated Roadmap—FY2011-2036*, 19-21.
[53] Ibid., 52.

2014[54], and a secure, wideband, internet-protocol (IP) based, self-healing network waveform that works for UAS is not likely until the beginning of the next decade.[55] Advancements in UAS antenna technology are not forecast to be technologically ready until the 2019 timeframe,[56] and must be developed concurrently to support future bandwidth alternatives. Air Force and Navy theater-capable UAS will continue to outstrip MILSATCOM bandwidth and remain dependent on leased commercial SATCOMs for the foreseeable future, a vulnerability in any contested threat environment.[57] Critical enabling technologies such as optical communication, while demonstrating promise toward mitigating dependence on commercial SATCOM, are not forecast for maturity until 2025.[58]

A separate joint effort led by STRATCOM and JFCOM is underway to standardize and resource the communications infrastructure for a Joint Aerial Layer Network (JALN) that enables a resilient, multi-spectral, secure, wideband area network.[59] This long-term effort, critical for UAS C3 in a 2035 threat environment, depends on coordinated investment by the services in several expensive acquisition programs and could be hindered by cost, schedule, or funding delays.

Recommendations and Conclusion

The time is now to address the issues of joint interoperability and future C3 of theater-capable UAS. Although systems such as Predator, Sky Warrior and Global Hawk have been

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[54] United States Air Force. "MQ-1/9 PEM Brief." 9 September 2010. PowerPoint Presentation

[55] Department of Defense, *Draft Unmanned System Integrated Roadmap, FY2011-2036, "C*ommunications Technology TRL Timeline", 76.

[56] Ibid.

[57] United States Air Force, *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047*, 43.

[58] Department of Defense, *Draft Unmanned System Integrated Roadmap, FY2011-2036*, "Communications Technology TRL Timeline, 76.

[59] United States Air Force Draft Plan, *The Air Force Vision for Aerial Layer Networking in 2024*. (Washington, D.C., Headquarters, United States Air Force, Draft). JALN ICD approved 27 Oct 2009 with STRATCOM and JFCOM appointed as Co-leads.

touted as "obvious rapid acquisition success stories",[60] their expedited fielding outside normal acquisition processes has mortgaged the future joint synergy of these platforms. Continuing down the current path of fielding service-specific, proprietary UAS will magnify today's operational challenges, including bandwidth saturation and deconfliction, the inability to create a secure system network, and lack of interoperable design standards.

Though DoD and each of the services possess a strategic plan for UAS that touts joint interoperability, little of the actual work defining and implementing a standardized open architecture has been done. Concerted leadership from OSD and strong support from service acquisition communities, Congress, and defense industry partners is necessary to turn words into reality.

To begin to accomplish what is required for an effective, survivable UAS capability for the future, OSD and the services need to do the following:

Near Term:

1) ***Continue UAS Task Force and OSD/AT&L oversight and standardization efforts, expanding to include other common interfaces.*** OSD/AT&L Interoperability Integrated Process Team efforts have made progress in standardizing Common Ground Station (CGS) architecture and moving toward service-oriented architecture (SOI) for UAS software and sensor design and integration[61]. Expand work to include message format/data bus standardization. Hold services accountable for implementing baseline interoperability standards, emphasizing capability to share/re-use data between platforms.

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[60] James Hasik. "Al Qaeda doesn't have a JCIDS process—thoughts on institutionalizing rapid acquisition." http://www.jameshasik.com/weblog/2010/10/al-qaeda-doesnt-have-a-jcids-processthoughts-on-institutionalizing-rapid-acquisition.html. (accessed 17 Jan 2010), 1.

[61] Rich Ernst. "OUSD (AT&L) PSA, Unmanned Warfare Common Architecture Status." September 10, 2010. PowerPoint Presentation, slide 2-6.

2) ***Continue Joint UAS Center of Excellence efforts to update UAS Joint CONOPs, foster inter-service agreements on cross-component ops for theater-capable UAS, and lead UAS NAS and ICAO Airspace Integration***[62]***.*** Codifies corporate knowledge. Optimizes interoperability, flexible automation and manned-un-manned (MUM) teaming.

3) ***Establish a Global Operations Center for C2 of BLOS theater-capable UAS.*** Lead Joint assessment of dynamic UAS C2 to support multiple COCOMS simultaneously. Will have implications on Joint Doctrine, Organization, Apportionment, and Facilities.

4) ***Standardize and field first-generation CDL to provide networked COP. Fund Joint Research and Development efforts in optical communication, automation and AI, and Joint Aerial Layer Network development.*** Joint oversight critical to fund multi-spectral, resilient capabilities, such as "Surrogate satellites," and "Maingate"[63] alternatives to leased commercial SATCOM. AI/automation advances critical to UAS capability in contested/denied access environments.

Mid-Term:

5) Merge JFCC-ISR and JFACC tasking processes for theater-capable UAS. Optimize theater-capable UAS tasking, C2.

[62] United States Joint Forces Command. *Joint Concept of Operations for Unmanned Aircraft Systems*, Appendix G.
[63] Dr. Larry B. Stotts, Deputy Director, DARPA/STO. "MILCOM 2010 Panel on Free Space Laser Communication--Moving Toward Transition." MILCOM 2010 Briefing Slides, PowerPoint Presentation, slide 5.

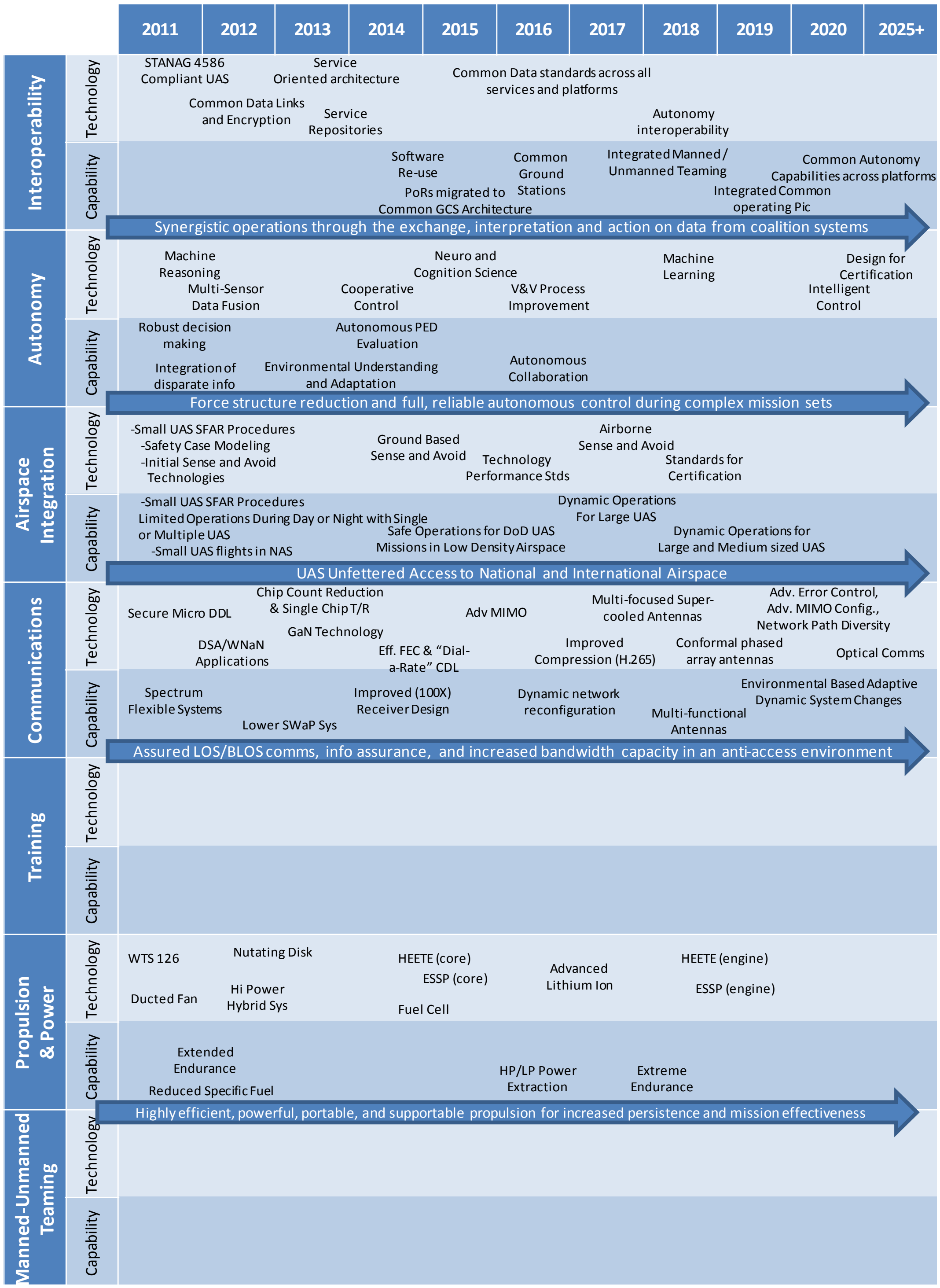
Long-Term:

6) ***Field Joint communications infrastructure to enable JALN. Incorporate advances in multi-spectral communication to mitigate dependence on commercial SATCOM. Leverage JALN, advances in flexible autonomy and MUM to refine and optimize Joint UAS CONOPS.*** Technology advances, fielded with a focus on interoperability and network resiliency, finally enable the 2035 vision for theater-capable UAS envisioned at the outset of this paper.

This paper calls for reform of the current UAS acquisition system, highlighting a need for standardization to enable joint interoperability. A reformed process must balance effectiveness and affordability with timeliness in delivering warfighter capability. Evolving UAS C3 challenges must be overcome to achieve a resilient and securely-networked system of joint theater-capable UAS. Precisely how this reform and standardization will best be accomplished is a question that warfighters, acquisition experts, and the defense industry must work together to resolve. Achieving DoD's long-term vision for UAS, leveraging their strengths of persistence, versatility and reduced risk to human life, provides a vital and synergistic capability toward countering the threats of 2035. Failing to do so, however, may accomplish the enemy's mission of degrading or denying UAS effectiveness well-before this time.

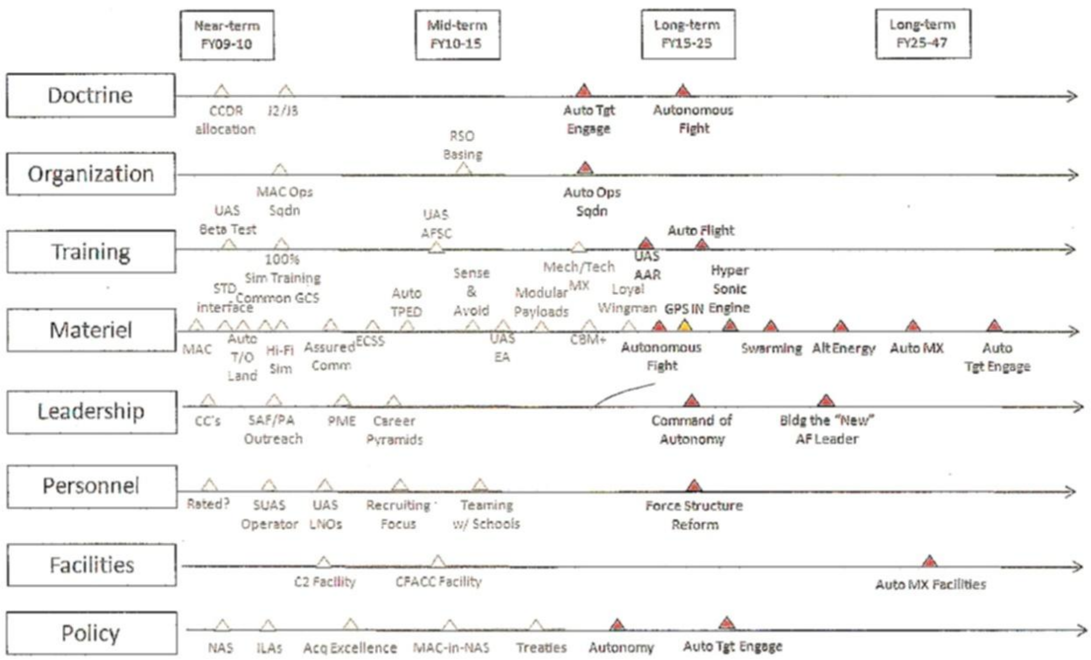
Appendix A: DoD 2011 Unmanned Systems Roadmap[64]

[64] Reprinted from: Department of Defense, *DRAFT Unmanned Systems Integrated Roadmap—FY2011-2036*,76.


2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2025+
Interoperability
Technology
STANAG 4586 Compliant UAS
Service Oriented architecture
Common Data standards across all services and platforms
Common Data Links and Encryption
Service Repositories
Autonomy interoperability
Capability
Software Re-use
Common Ground Stations
Integrated Manned / Unmanned Teaming
Common Autonomy Capabilities across platforms
PoRs migrated to Common GCS Architecture
Integrated Common operating Pic
Synergistic operations through the exchange, interpretation and action on data from coalition systems
Autonomy
Technology
Machine Reasoning
Neuro and Cognition Science
Machine Learning
Design for Certification
Multi-Sensor Data Fusion
Cooperative Control
V&V Process Improvement
Intelligent Control
Capability
Robust decision making
Autonomous PED Evaluation
Integration of disparate info
Environmental Understanding and Adaptation
Autonomous Collaboration
Force structure reduction and full, reliable autonomous control during complex mission sets
Airspace Integration
Technology
-Small UAS SFAR Procedures
-Safety Case Modeling
-Initial Sense and Avoid Technologies
Ground Based Sense and Avoid
Airborne Sense and Avoid
Technology Performance Stds
Standards for Certification
Capability
-Small UAS SFAR Procedures
Limited Operations During Day or Night with Single or Multiple UAS
-Small UAS flights in NAS
Dynamic Operations For Large UAS
Safe Operations for DoD UAS Missions in Low Density Airspace
Dynamic Operations for Large and Medium sized UAS
UAS Unfettered Access to National and International Airspace
Communications
Technology
Secure Micro DDL
Chip Count Reduction & Single Chip T/R
Adv MIMO
Multi-focused Super-cooled Antennas
Adv. Error Control, Adv. MIMO Config., Network Path Diversity
GaN Technology
DSA/WNaN Applications
Eff. FEC & "Dial-a-Rate" CDL
Improved Compression (H.265)
Conformal phased array antennas
Optical Comms
Capability
Spectrum Flexible Systems
Improved (100X) Receiver Design
Dynamic network reconfiguration
Environmental Based Adaptive Dynamic System Changes
Lower SWaP Sys
Multi-functional Antennas
Assured LOS/BLOS comms, info assurance, and increased bandwidth capacity in an anti-access environment
Training
Technology
Capability
Propulsion & Power
Technology
WTS 126
Nutating Disk
HEETE (core)
ESSP (core)
Advanced Lithium Ion
HEETE (engine)
ESSP (engine)
Ducted Fan
Hi Power Hybrid Sys
Fuel Cell
Capability
Extended Endurance
Reduced Specific Fuel
HP/LP Power Extraction
Extreme Endurance
Highly efficient, powerful, portable, and supportable propulsion for increased persistence and mission effectiveness
Manned-Unmanned Teaming
Technology
Capability

Appendix B
USAF Long-Term (FY 25-47) Path Toward Full Autonomy[65]

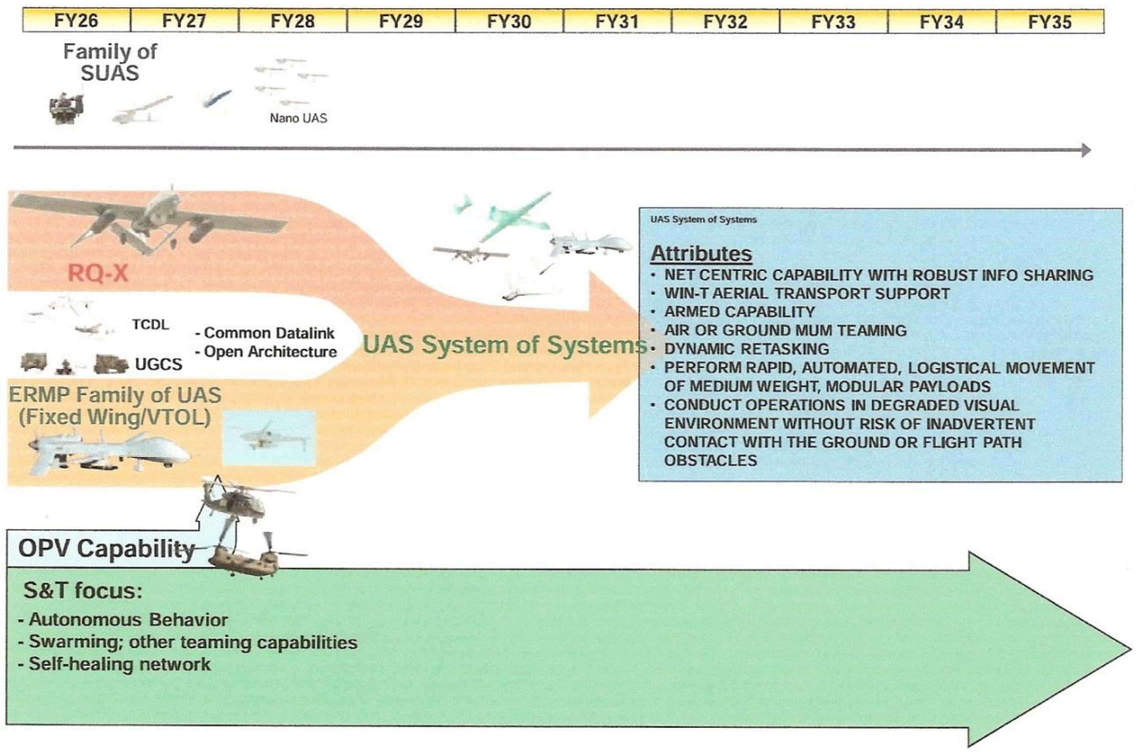
4.6.4 Long Term (FY25-47) Path Toward Full Autonomy



[65] Reprinted from: United States Air Force. *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047*, 50.

Appendix C

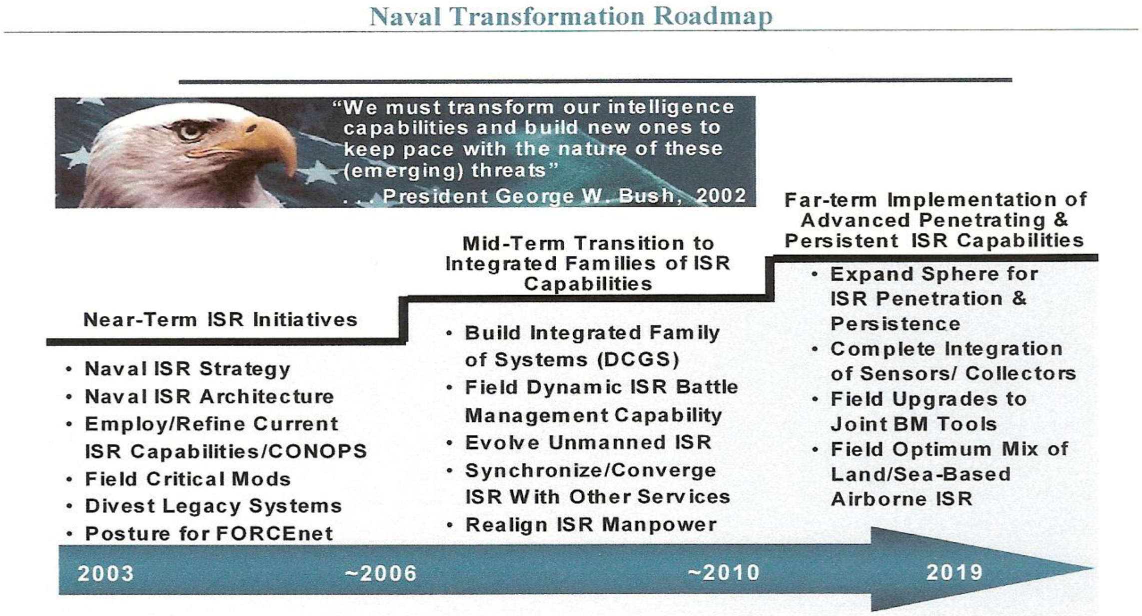
US Army UAS Far-Term Implementation[66]



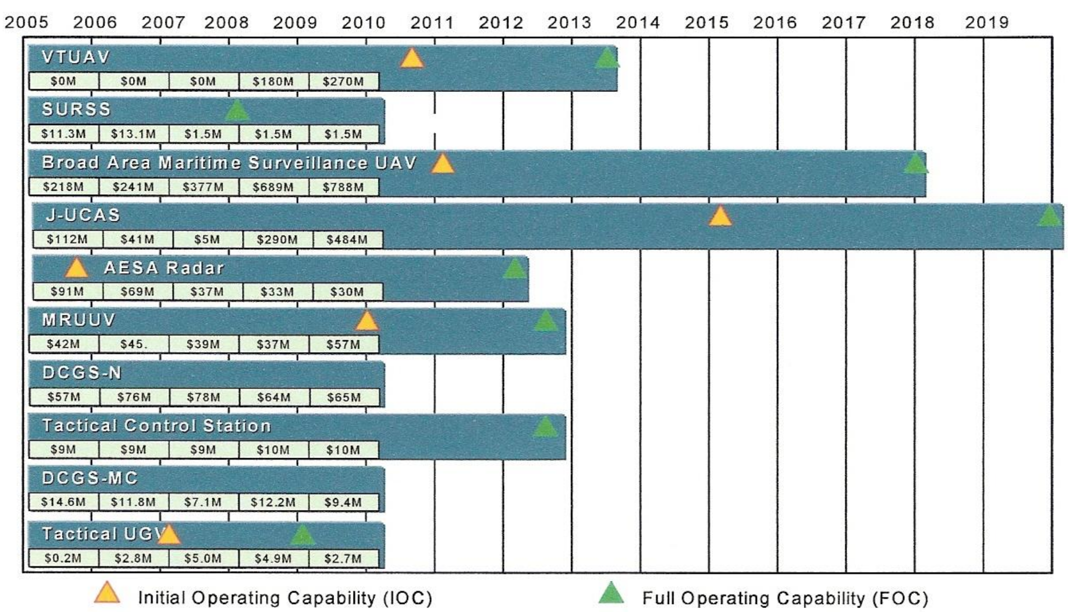
66 Reprinted from: United States Army UAS Center of Excellence, *U.S. Army Roadmap for UAS 2010-2035.* (Fort Rucker, AL: United States Army UAS Center of Excellence, 2010), 64.

Appendix D

Naval ISR Strategy and Transformational Roadmap[67]



Naval Programs Supporting Transformation of FORCEnet ISR



[67] Reprinted from: United States Navy, *Naval Transformation Roadmap 2003, Assured Access and Power Projection from the Sea.* Washington, D.C.: Headquarters, United States Navy, 2003, 70, 72

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